An Infrastructure for Passive Network Monitoring of Application Data Streams

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Self Configuring Network Monitor (SCNM)

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- **SCNM is a passive monitoring system designed to address the following issues:**
  - **Ability for network *users* to monitor their traffic as it traverses the network**
    - SNMP provides a very coarse level of monitoring, and end users rarely have permission to access this data
    - DAG-based systems provide packet capture ability, but end users don't have access to this data
  - **Ability to identify the source of network congestion or other problems (e.g: is packet loss a LAN or WAN issue)**
  - **Ability for application developers to characterize their own traffic, and how it is impacted by the network (e.g.: Jitter)**
  - **Protocol analysis and debugging**
    - Often not possible to capture packet traces at the sending host
      - tcpdump will often lose packets when trying to capture a high bandwidth stream

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Self Configuring Network Monitor (SCNM) Goals

- Based on low cost, “off the shelf” components
- Easy to activate
- Secure
  - Users can monitor their own data, without the need to involve network administrators
- Easy to deploy, configure, and administer

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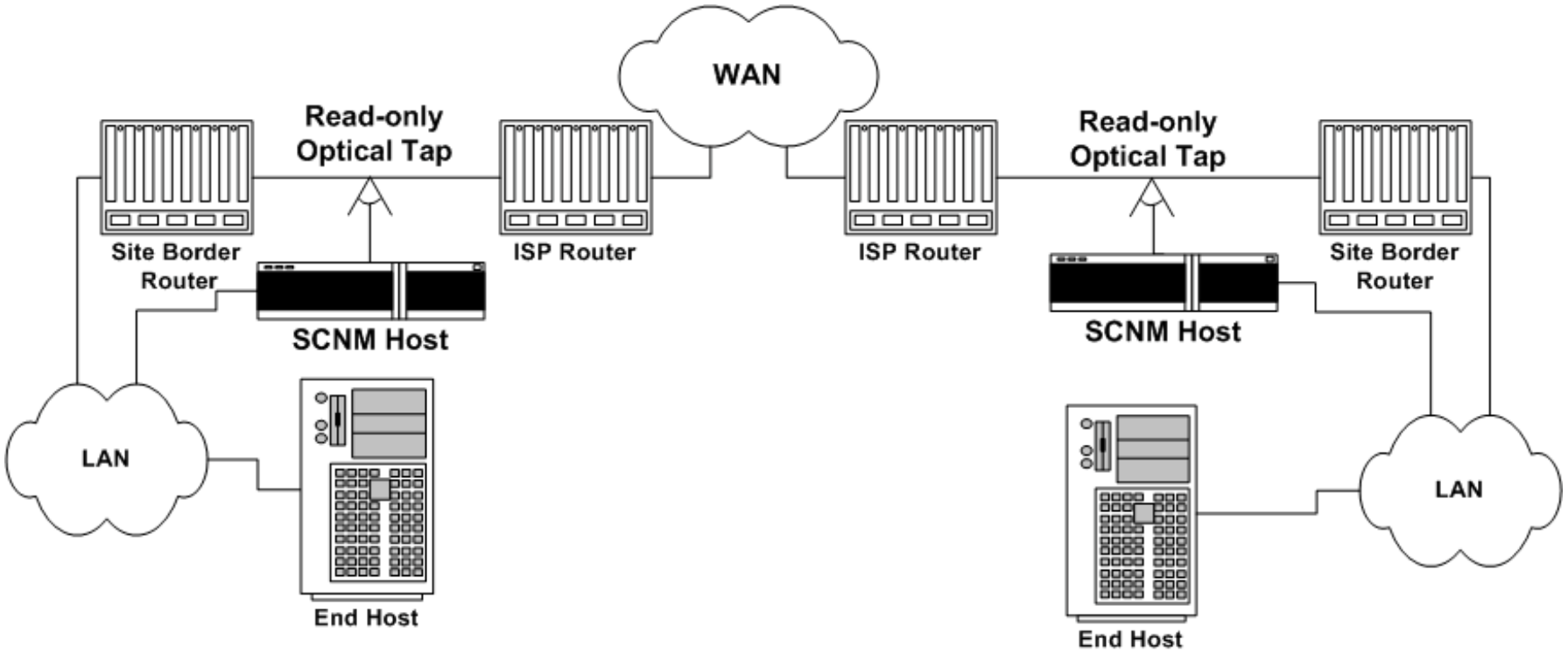
Typical Deployment



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Monitor Activation

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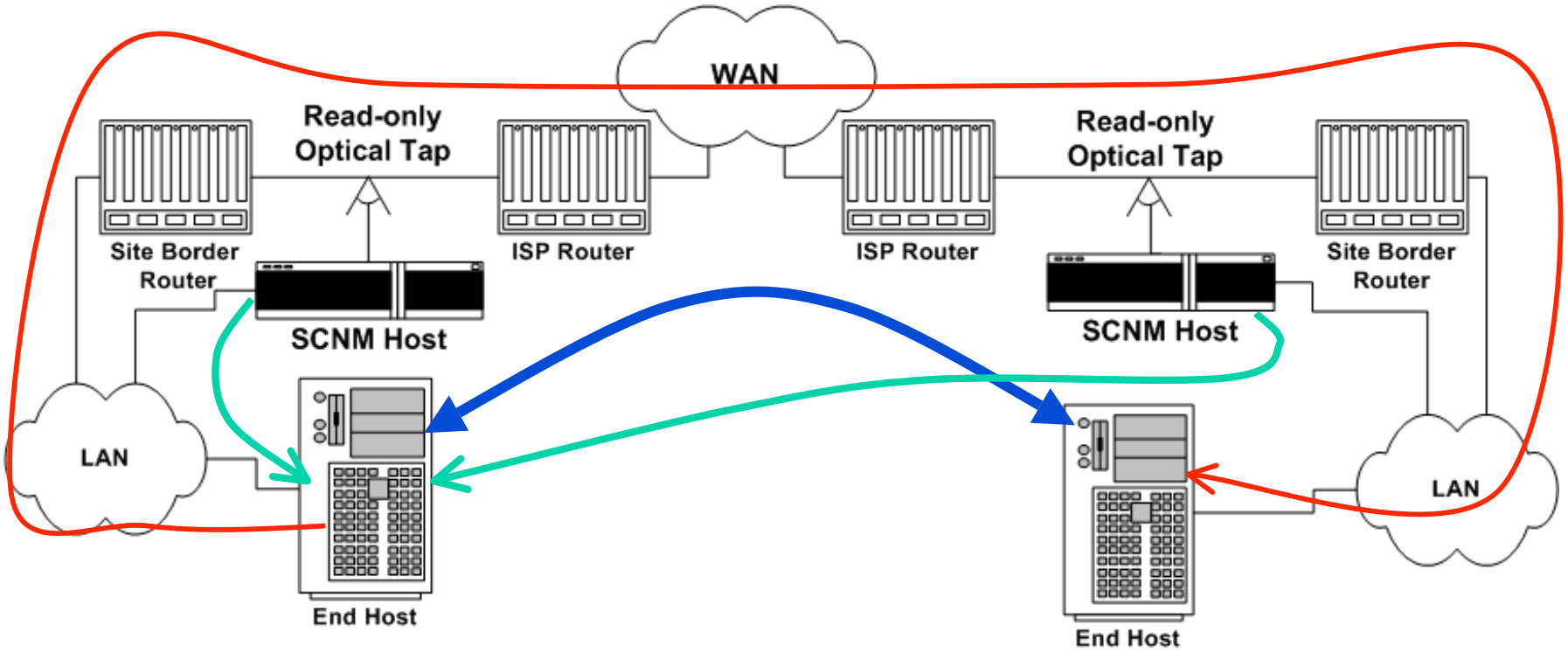

Data Flow

Activation packet

Packet Headers

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Typical Result

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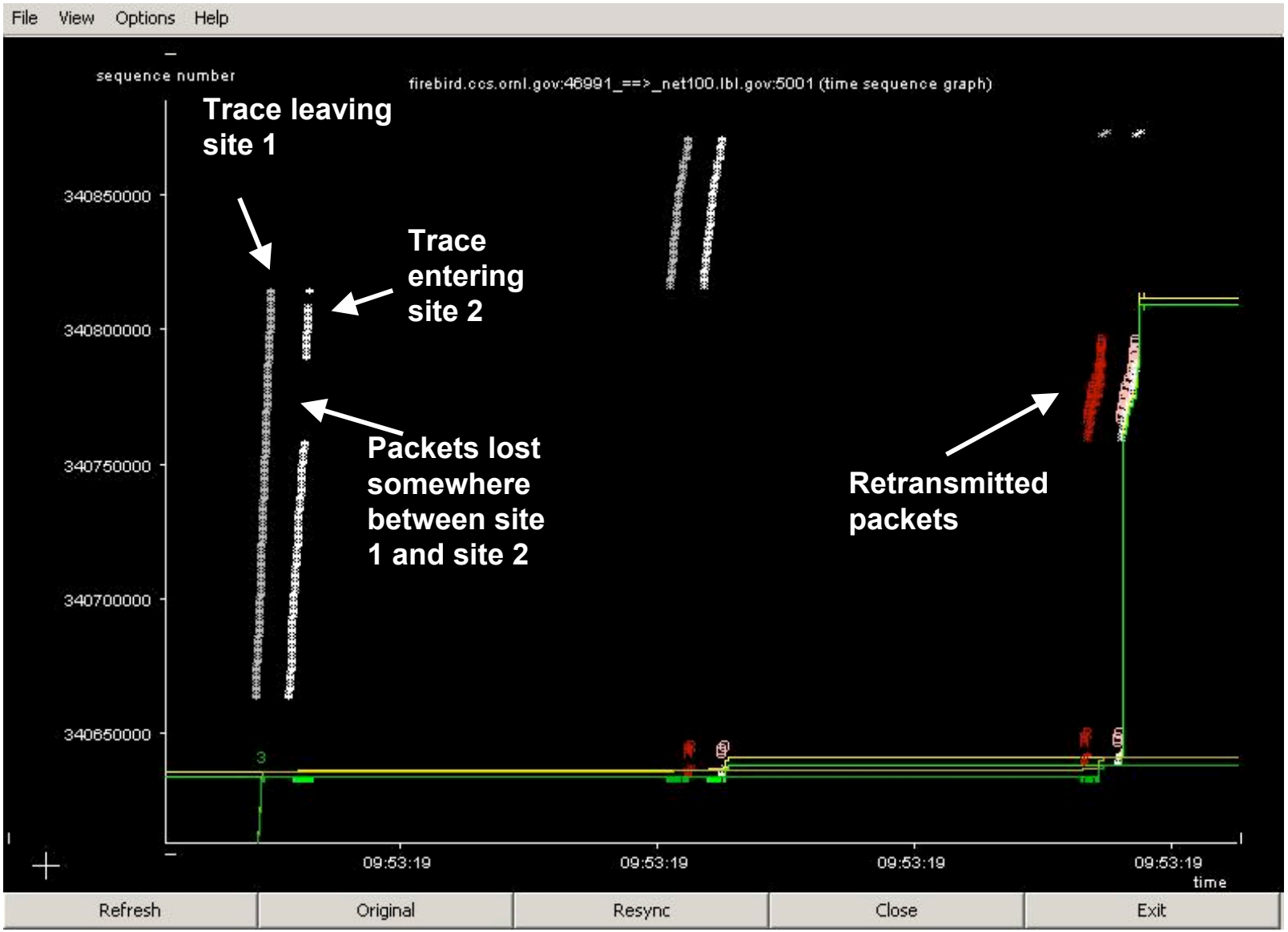

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Passive Monitor Host

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- Installed at critical points in the network (i.e.: next to key routers)
- Uses read-only 1000BT fiber tap (e.g.: from Netoptics)
- Passively captures packet headers of monitored traffic
  - Daemon based on libpcap (used in NIMI)
- Configured and activated by application end-points
  - Without network administrator involvement
- Has an additional network interface (usually on an internal network) used for administering the SCNM host and sending monitoring output data

Activation and Configuration

- Activation packets are sent from the application endpoint using UDP and a well known port
  - Sent to the other endpoint of application traffic
  - All monitors along the data path capture activation packet
- Activation packets specify which traffic to monitor
  - Must be the traffic for the same source/dest
- The monitor configures itself to monitor the traffic
- Activation packets are resent periodically to refresh monitor state
- Monitor times out if no activation packets are received

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System Design

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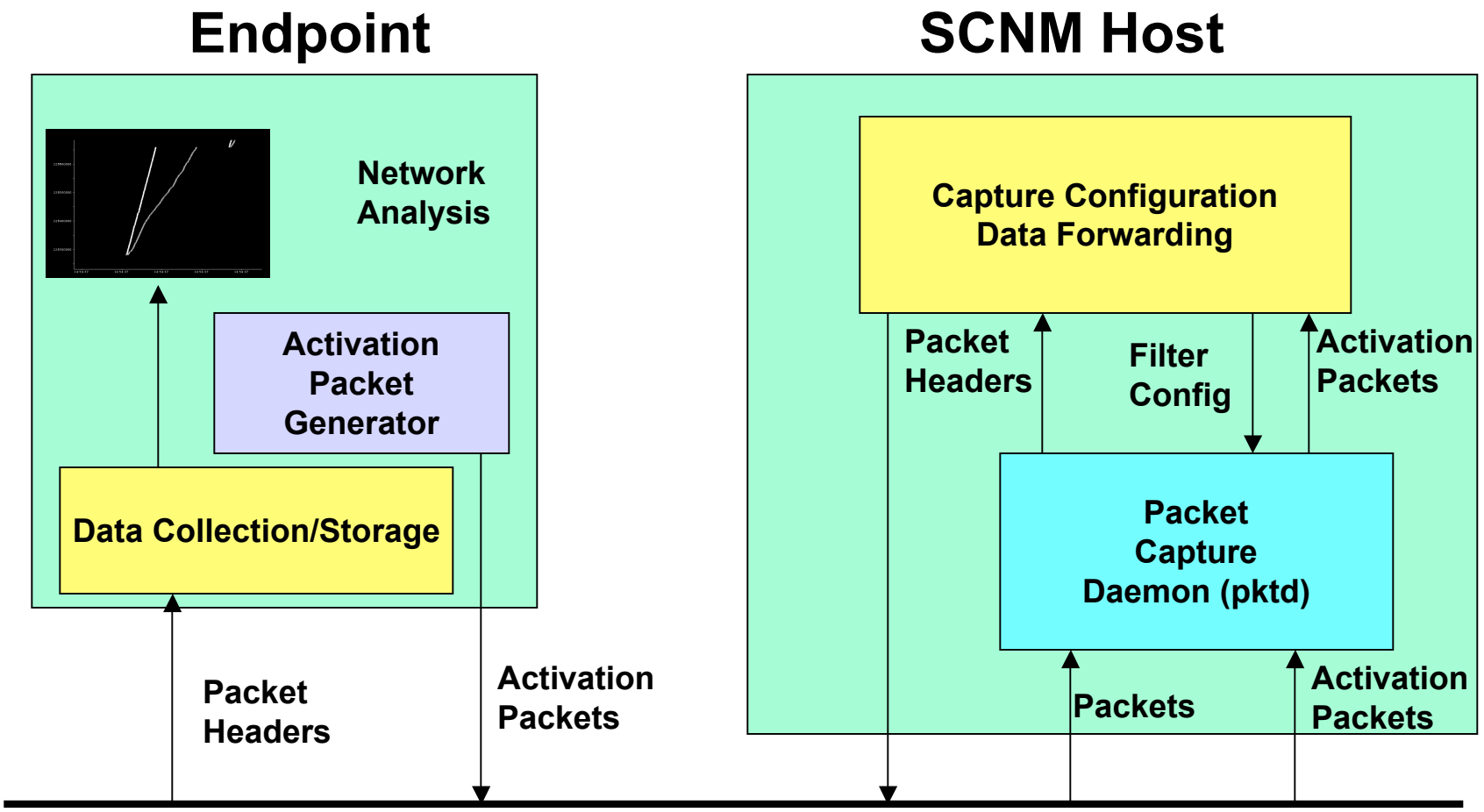

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Security Model

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- Monitor host system installed and maintained by network administrators
- A user is only allowed to monitor their own data
  - Or other streams from the same sending host
- The activation packet must be traveling between the source and destination of the traffic to activate monitoring
- The SCNM host will only send resulting packet headers back to the source of the activation packet
- SCNM host logs all monitoring requests
- Network Admin mode (future):
  - Use signed and authorized activation packets to allow the ability to:
    - Activate monitoring from a host that is not one of the endpoints
    - Send packet headers to a host that is not one of the endpoints

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Implementation Issues

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- Currently deployed packet capture hosts (almost 2 years old HW)
  - FreeBSD
  - SuperMicro 370DL motherboard
  - single P-III Xeon 933MHz CPU
  - PCI 64bit/66MHz IO bus, 133 MHz DIMMs
  - 2 SysKonnect PCI 64 bit 1000BT NICs
    - one for capturing packets in each direction.
- Many performance issues had to be addressed, including:
  - Interrupt moderation
  - Timestamping packets in the NIC
  - Reducing kernel memory copies
- Using this hardware we have monitored TCP flows of up to 940 Mbits/sec for several minutes

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Interrupt Moderation Issues

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- Interrupt moderation helps reduce the CPU requirements, but:
- Interrupt moderation period must be short enough to:
  - Avoid running out of kernel receive buffer descriptors
  - Avoid large delays in packet processing
- Drawback of interrupt coalescing:
  - Kernel is no longer able to assign accurate timestamps to the arriving packets.
- Some network cards (including SysKonnect) have an onboard timestamp register
  - Can provide information on the exact packet arrival time, and pass this timestamp to the system buffer descriptor
- We have modified the FreeBSD SysKonnect driver and BPF implementations to use the NIC timestamp, instead of the system clock timestamp
  - We are currently using a 1 ms interrupt moderation period (default is 200 µs)

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Memory Bandwidth Issues

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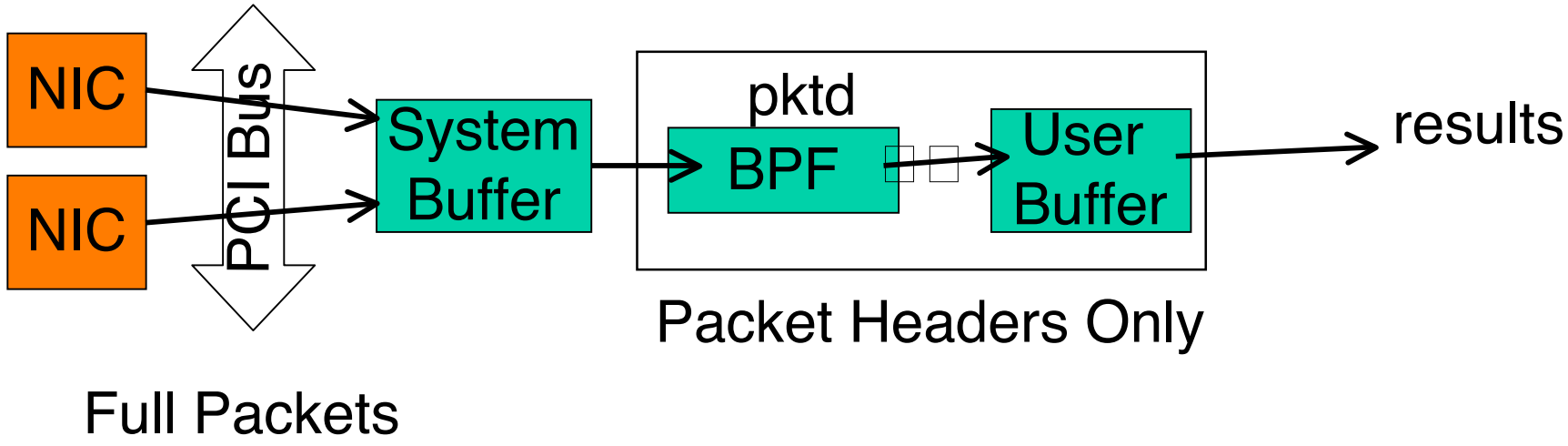

- **Memory bandwidth is the most critical HW factor in data capture**
- **Assuming bidirectional traffic, each of the 2 NICs transfer data to the system bus at up to 1 Gbit/s = 125 MBytes/second**
- **Memory bandwidth required is:**
  - **2 x 125 MBytes/sec + around 10% for multiplexing and forwarding packet headers ≈ 300 MBytes/sec**

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Memory Issues: Current PC Hardware

- Memory bandwidth is up to around 1 GByte/second
  - (e.g: ServerWorks P4DL6 motherboard; 466 MHz DDR memory; 64-bit/133MHz PCI-X bus, 10 GigE NIC)
  - Bottleneck is both the PCI-X bus and the DDR memory
- This system should be capable of capturing almost 4 Gbits/sec (500 MBytes/sec) of bidirectional traffic:
  - 2 x 500 MBytes/sec + 10% needs 1100 MBytes/sec of memory bandwidth
- This is a hardware requirement
  - There are also a number of software tuning issues that must be addressed to achieve this capability
- Will begin testing this configuration soon

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Header Compression in *pktd*

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- Even though we are only capturing headers, the amount of data collected is quite large
  - For example, a 10 second capture of a 300 Mbps TCP stream contains over 20 MB of header data.
- To reduce this, we have implemented packet header compression
  - Based on the approach used by CSLIP
- Works quite well
  - Achieves an average lossless compression ratio of about
    - 6:1 for UDP headers
    - 4:1 for TCP headers.

Visualization / Analysis Tool

- **SCNMPlot**
  - **Uses tcptrace files for input**
    - http://www.tcptrace.org/
  - **Enhanced version of xplot tool**
    - Allowed multiple input files
    - “Nudge” feature

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Observing Packet Jitter

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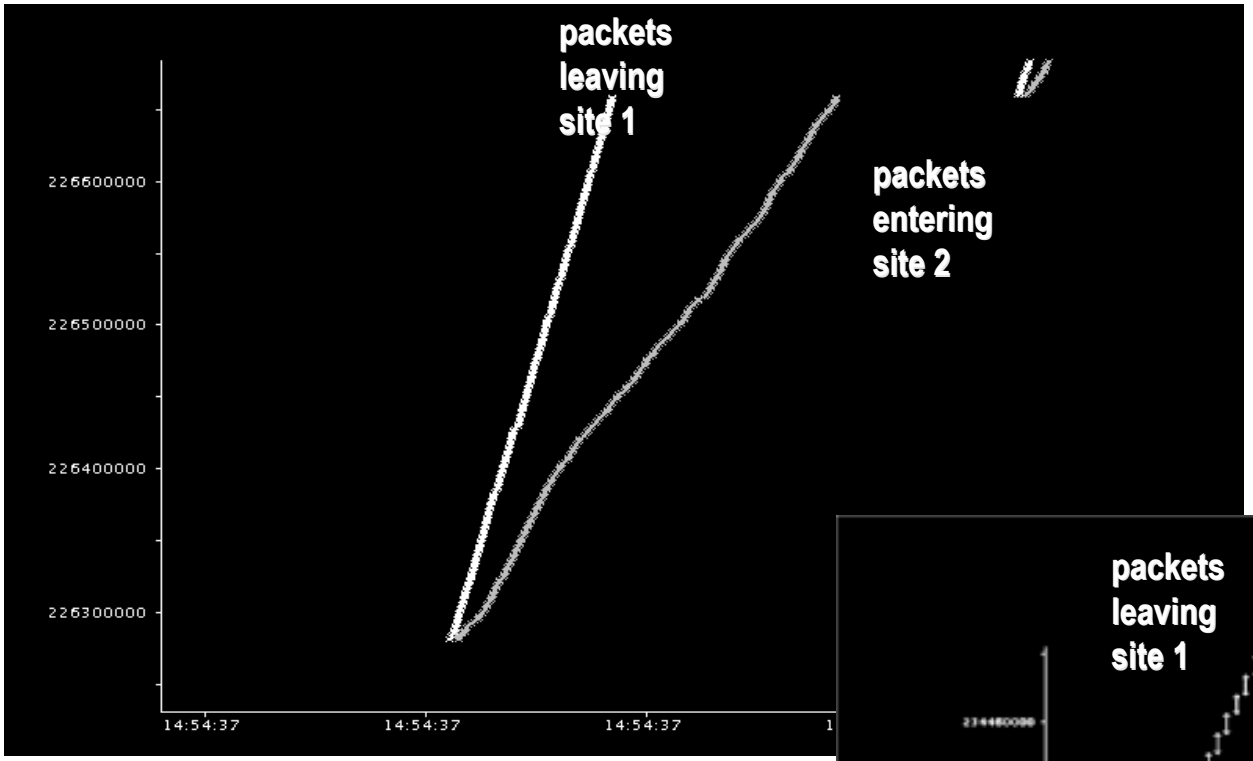

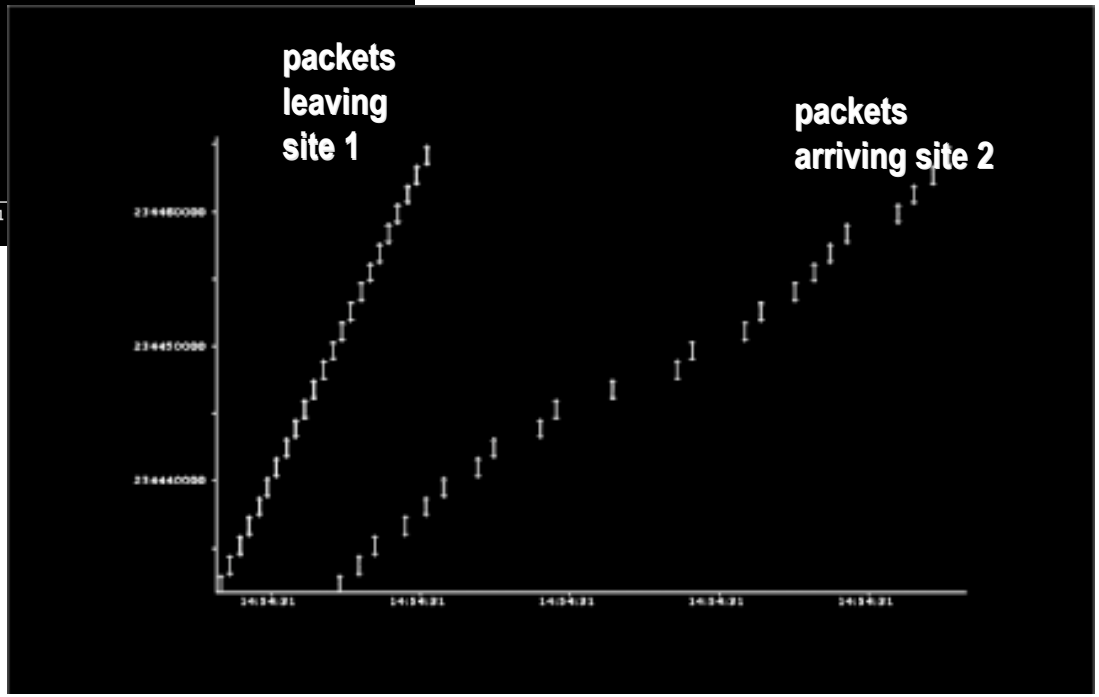

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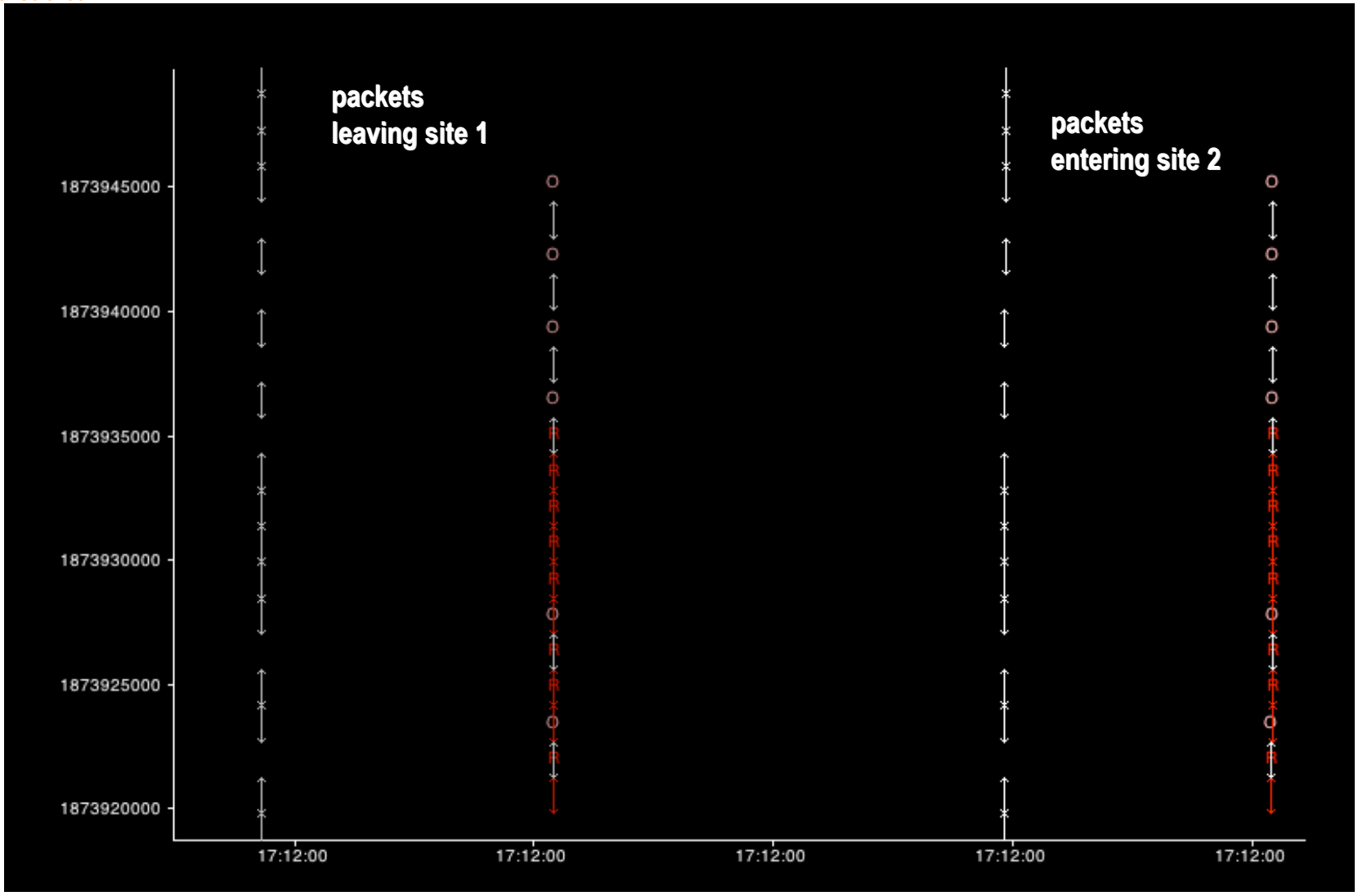
Results: Loss on Sender and Receiver LAN



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Results: Linux SACK Bug (not seen in local tcpdump)

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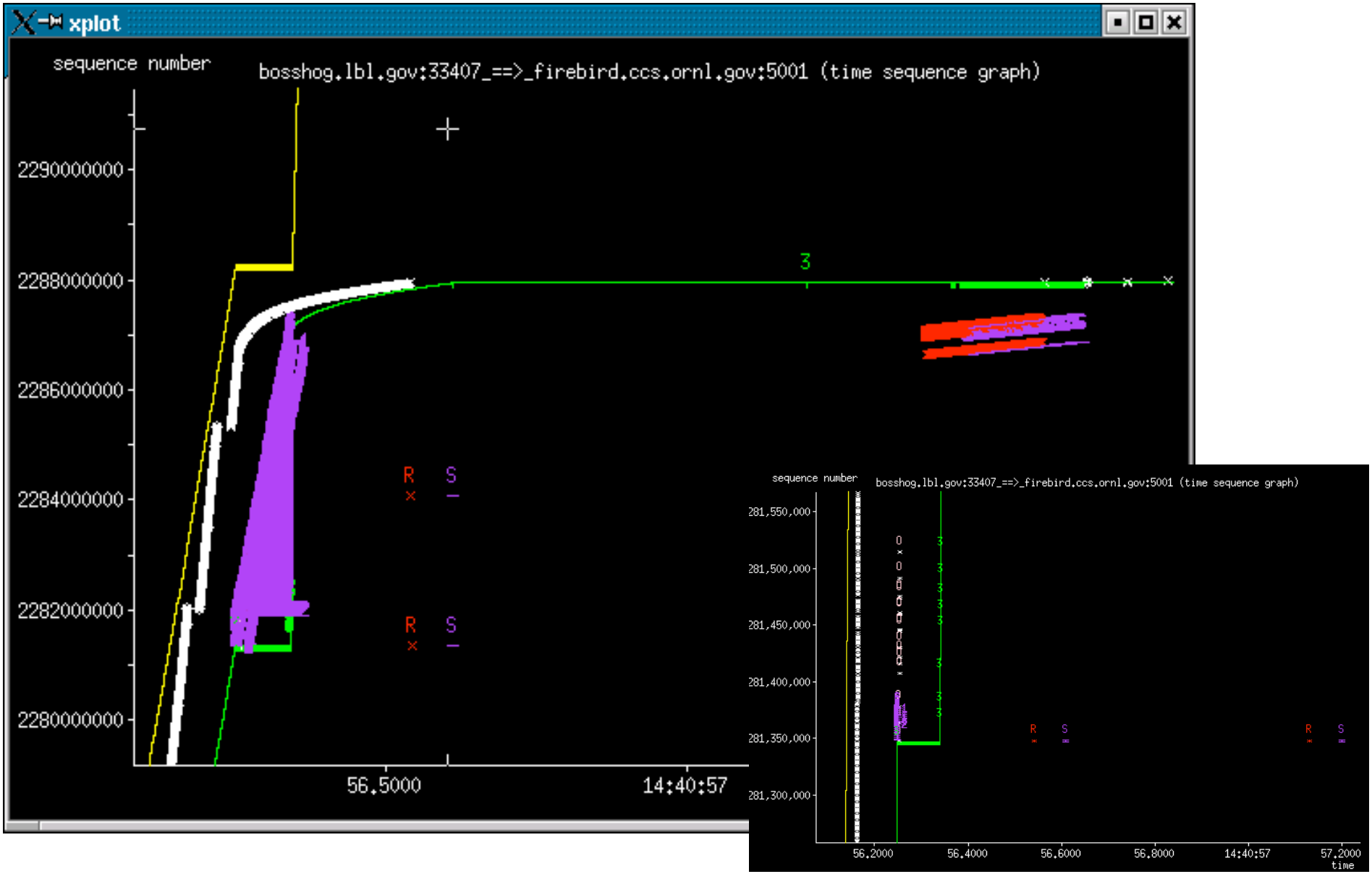

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Results: TCP throttling

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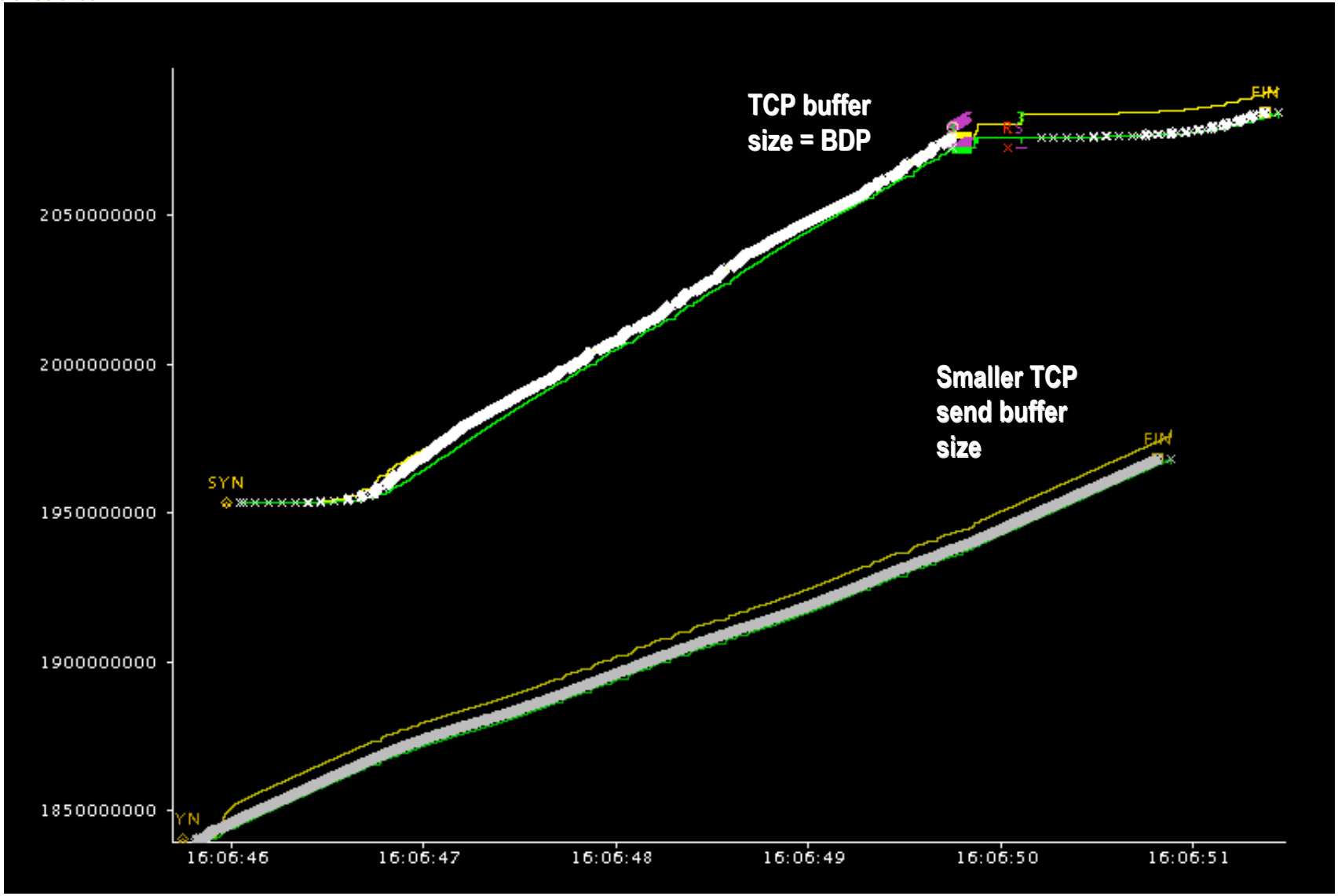

Deployment

- Current installations
  - National Energy Research Scientific Computing Center (NERSC)
  - Lawrence Berkeley National Lab (LBNL)
  - Oak Ridge National Lab (ORNL)
  - Stanford Linear Accelerator Center (SLAC)

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Current / Future Work

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- **Deployment at more sites**
- **Network administrator mode**
  - **Use signed and authorized activation packets to allow the ability to:**
    - Activate monitoring from a host that is not one of the endpoints
    - Send packet headers to a host that is not one of the endpoints
- **Capture at 10 GigE rate**

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Further Information

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- URL
  - http://www-didc.lbl.gov/SCNM/
- Contacts
  - BLTierney@lbl.gov
  - DAAgarwal@lbl.gov
  - j_guojun@lbl.gov
  - chema@cs.berkeley.edu

Extra Slides

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Data Path

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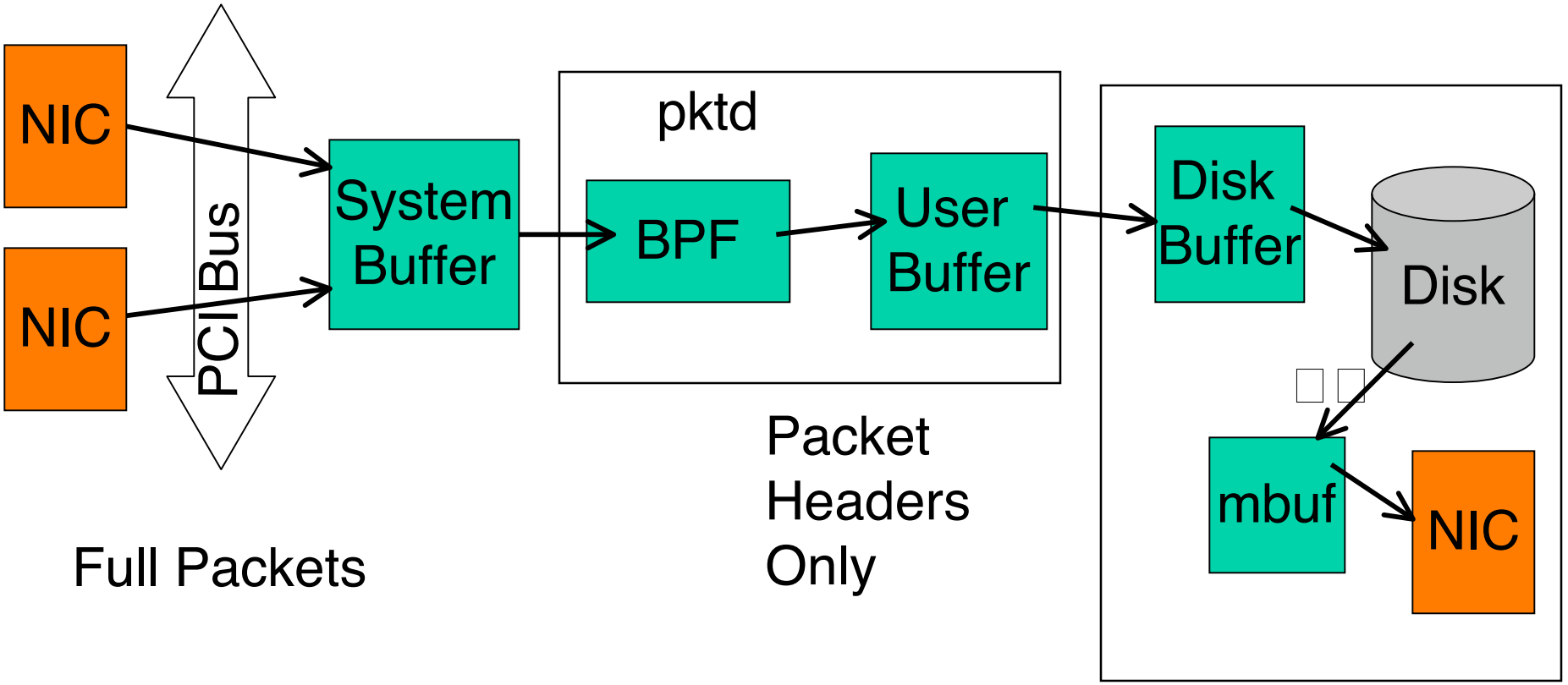

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Another view of the Linux SACK Bug

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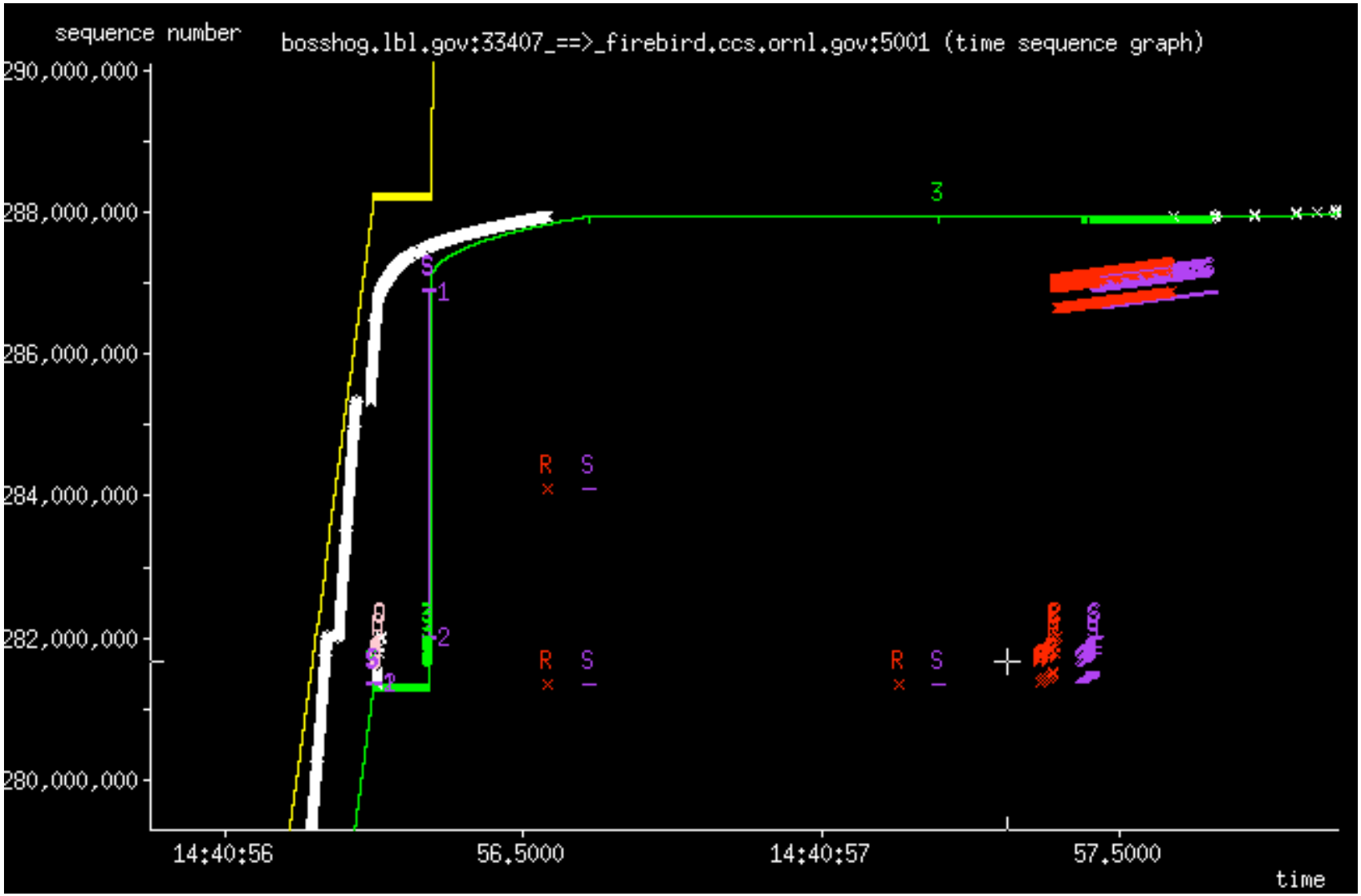

More on Interrupt Moderation

- **The maximum interrupt interval depends on**
  - **average packet size**
  - **space the kernel reserves for incoming data from the NIC**
    - number of per-packet kernel receive buffers (N)
  - **The maximum interrupt interval can thus be calculated as:**
    - time = N * average_packet_size / line_speed
  - **Defaults for the SysKonnect driver**
    - 256 kernel receive buffers
    - 200 ms interrupt servicing frequency
  - **For an average packet size of 1000 bytes:**
    - 256 receive buffers will become occupied after 2 ms.
  - **If the packet size is l500-bytes, the interrupt interval can be as large as 3 ms**
  - **Increasing the number of receive buffers will allow a longer coalescence period**
    - however, a large number of receive buffers requires large system memory resources